Pacific-Basin Finance Journal 53 (2019) 399–409

Contents lists available at ScienceDirect

Pacific-Basin Finance Journal

journal homepage: www.elsevier.com/locate/pacfin

# The wealth effects of the announcement of the Australian carbon pricing scheme☆

Jianlei Han, Martina K. Linnenluecke, Zheyao (Terry) Pan, Tom Smith*

*Faculty of Business and Economics, Macquarie University, North Ryde, NSW, Australia*

ARTICLE INFO

*Keywords:*
Australian Carbon Pricing Scheme
Carbon tax
Event study
Value effect
News effect
Probability of legislature passage

*JEL classifications:*
G14
G18
Q54
Q58

ABSTRACT

In this study, we examine the wealth effects associated with the announcement of the Australian Carbon Pricing Scheme (the "carbon tax"), made by the then Prime Minster Julia Gillard on 24 February 2011. Building on studies that use the event study method originally developed by Fama et al. (1969) and Ball and Brown (1968), we propose a novel approach to analyzing announcements with unresolved uncertainty. With this approach, we separate out the news effect and the value effect associated with the announcement of the Australian Carbon Pricing Scheme. Our findings show that the average news effect associated with the announcement is 1.11% (A$254 million dollars), indicating that the market was favorably disposed towards the news that the government was taking action on climate change. The average value effect was −4.46% (−A$1.12 billion dollars), indicating that the scheme destroyed significant value for existing firms. The announcement of the Australian Carbon Pricing Scheme was more value-destructive for carbon-intensive firms (−6.97%) than for the other firms (−3.67%). The method presented in this study can be applied to any policy announcements with unresolved uncertainty

## 1. Introduction

Recent scientific findings (IPCC, 2018; Rockström et al., 2009; Steffen et al., 2015) have generated much concern regarding the level and rate of global environmental change caused by human activity. Urgent action is required to either slow down or reverse adverse trends on global scales, such as the increasing levels of greenhouse gas emissions into the atmosphere (IPCC, 2014). Internationally, the global response to climate change has seen progress through the United Nations Framework Convention on Climate Change (UNFCCC) which led to the adoption of the Kyoto Protocol (committing 38 industrialized countries and the European Community to emissions reductions) and the subsequent adoption of the 2015 Paris Agreement (setting out a broader global climate deal ratified by 195 governments). The ultimate aim of the UNFCCC is to stabilize greenhouse gas emissions in the atmosphere at a level that prevent dangerous human-induced interference with the climate system. On a national

☆ Two of the authors (MKL and TS) acknowledge funding from the Australian Research Council (ARC), grant number DP160103425. Two of the authors (JH and ZP) acknowledge funding from the Accounting and Finance Association of Australia and New Zealand (AFAANZ) 2018 Research Grant. We thank participants at the 2017 AFAANZ conference for their insightful comments, in particular the discussant Ellie Chapple.

* Corresponding author.
*E-mail addresses:* jianlei.han@mq.edu.au (J. Han), martina.linnenluecke@mq.edu.au (M.K. Linnenluecke), terry.pan@mq.edu.au (Z.T. Pan), tom.smith@mq.edu.au (T. Smith).

https://doi.org/10.1016/j.pacfin.2018.12.006
Received 30 July 2018; Received in revised form 7 November 2018; Accepted 21 December 2018
Available online 23 December 2018
0927-538X/ © 2018 Elsevier B.V. All rights reserved.

level, many countries (and especially those with commitments under Kyoto) have begun to introduce relevant policies such as carbon taxes and emission trading schemes[1] to drive the transition to a low carbon economy and fulfil their international obligations.

Commentators and researchers have debated the economic burden associated with the introduction of carbon taxes and emission trading schemes for different countries and industry sectors. In response, a body of research has emerged that focuses on the question of how environmental policies impact economic activity, and how resulting wealth effects for the whole market can be accurately estimated (e.g., Pindyck, 2013). However, estimations of wealth effects are difficult in situations where environmental policy announcements are surrounded by uncertainty regarding whether the policy will finally be implemented or not. For example, the announcement by any government that it will implement a carbon emission reduction scheme or carbon taxation policy does not automatically result in the adoption of these policies – they often need to pass through various governmental approval stages on a national level. Consequently, there is an identification problem when announcements have unresolved uncertainty. In this situation, the traditional event study method of Fama et al. (1969) and Ball and Brown (1968) cannot be applied because the price on announcement contains an outcome probability parameter as well as outcome price parameters (Barraclough et al., 2013; Bhagat et al., 2005; Linnenluecke et al., 2016).

To overcome these limitations of traditional event study methodologies, we propose a novel approach to analyzing announcements with unresolved uncertainty. Specifically, we build upon the approach developed by Barraclough et al. (2013) and Borochin and Golec (2016) and demonstrate its application by examining the wealth effects associated with the announcement of the Australian Carbon Pricing Scheme (the "carbon tax"), made by the then Prime Minster Julia Gillard on 24 February 2011. Using information from stock and options markets, this approach uncovers the probability and outcome parameters and enables the price change on announcement to be split into a news effect and a valuation effect. We apply our method to a sample of 33 Australian stocks with traded options during the Gillard carbon tax announcement period. Our aim is to break the market reaction into probability of uncertainty resolution (i.e., the passage of the announced carbon tax measure), news effects and value effects. We anticipate that the news effect will be positive for the market as the announcement makes it clear that the Australian Government is taking serious action on climate change which threatens assets, profits and human capital. We anticipate that the value effect will be negative as the carbon tax will result in increased cash outflows for the affected firms.

The 2011 announcement by the then Australian Prime Minister Julia Gillard surprised the Australian public as Gillard had promised in the lead up to the 2010 election that "no carbon tax" would be introduced.[2] At the time of the announcement there was unresolved uncertainty regarding whether the Clean Energy Act would eventually be approved by the Lower House and the Senate. This uncertainty is material given the Labor Party was not the majority party at the time – the Gillard-led Labor party and the Greens needed to seek the support of the independent members of parliament to pass the proposed legislation package. As a result, this announcement is an ideal setting to adopt our approach to isolate the news effect and the valuation effect of the carbon pricing policy. The news effects of Australia taking a strong stance on climate change is important both economically for markets and politically for policy makers who are interested in making the economy robust to threats likely to be present in the coming decades. The valuation effects of the proposed carbon tax are of crucial importance for existing firms and shareholders as they affect long run profitability and viability.

Applying our method to a sample of 33 Australian stocks with traded options during the Gillard carbon tax announcement period, we estimate that investors assigned a 42.4% probability that the carbon tax legislation would eventually pass on the announcement date (24 February 2011). The estimation result indicates that investors perceived a large degree of uncertainty. Our findings show that the average news effect associated with the announcement is 1.11% (A$254 million dollars) for all 33 stocks, indicating that the market was favorably disposed towards the news that the government was taking action on climate change. The average value effect was −4.46% (−A$1.12 billion dollars) for all 33 stocks, indicating that the scheme destroyed significant value for existing firms. In contrast, the estimated average cumulative abnormal return (CAR) is −0.5%. The positive news effect indicates that the market viewed positively the news that government was taking decisive action on climate change. The negative value effect indicates that the carbon tax is value-destructive for existing firms as they will suffer higher costs. Previous studies (Ramiah et al., 2013, |2015) on the market reaction towards green polices in the Australian market typically document a negative effect using the standard CAR approach. Our results suggest that the negative effects stem primarily from the value effect instead of the news effect. Our findings also indicate that the announcement of the Australian Carbon Pricing Scheme was more value-destructive for carbon-intensive firms (−6.97%) than for the other firms (−3.67).

This study is structured as follows. In Section 2, we introduce the timeline of the Carbon Pricing Scheme in Australia. In Section 3, we describe the identification problem and then we solve the problem by incorporating options. In Section 4, we describe the data and sample selection process. In Section 5, we will present and discuss the estimation results. We will conduct robustness tests to check if our results are robust when stocks with confounding firm announcements (e.g., earnings announcement) are removed from the sample. For purposes of comparison, we will also adopt the intervening event method of Bhagat et al. (2005) for comparison. Section 6 provides a summary and offers conclusions.

[1] Information about implemented and proposed emission trading schemes is available via https://icapcarbonaction.com/en/. The World Bank also offers information on regional, national and subnational carbon pricing initiative(s) via https://carbonpricingdashboard.worldbank.org/

[2] We provide a more detailed introduction of the institutional background and timeline of the Gillard carbon tax in Section 2.

## 2. Uncertainty resolution, news effects and value effects

We treat the Gillard announcement on carbon tax[3] as the focal event since it is a surprise for the market and it involves unresolved uncertainty, that is, whether it can be passed by the Lower House and the Senate. A common approach to evaluating announcement effects of policies is to use the event study method originally developed by Fama et al. (1969) and Ball and Brown (1968).[4] This method has been applied widely to study the effects of emission disclosures (Griffin et al., 2017), including those made through the carbon disclosure project (CDP) (Kim and Lyon, 2011; Lee et al., 2015). The method has also been applied to the announcement of global greenhouse gas emission targets (Meinshausen et al., 2009), the introduction of emission trading schemes (Chapple et al., 2013; Ramiah et al., 2017), and the introduction of green policies in general (Ramiah et al., 2013, 2015).[5] However, while these studies typically focus on the abnormal returns of individual stocks or portfolios around the environmental policy announcement dates, they do not fully capture the wealth effects as they combine different types of information into a single observation. Below, we present a brief overview of the events and resulting uncertainty as a background to our study (an abbreviated overview is provided in the timeline in Table 1).

### 2.1. The introduction of the carbon pricing mechanism

On 24 February 2011, the then Australian Prime Minister Julia Gillard first announced plans to introduce legislation (The Clean Energy Act) to establish a Carbon Pricing Mechanism from 1 July 2012 onwards.[6] This policy measure, often dubbed as a "carbon tax", was a renewed attempt by the Labor Government to introduce carbon legislation following earlier unsuccessful attempts to introduce such legislation by the Labor Government under Rudd. The announcement of the Carbon Pricing Mechanism was surrounded by much political and public controversy given that Gillard had promised in the lead up to the 2010 election that "no carbon tax" would be introduced by her government if elected. The opposition saw the announcement of the Carbon Pricing Mechanism as an attempt to break an election promise. The Gillard Government argued that it never intended on introducing a "carbon tax" and that the Carbon Pricing Mechanism would entail a "fixed-price emissions trading scheme" which was meant to remain in place for 3–5 years in the lead-up to a full emissions trading scheme.[7] Given that carbon taxation and emissions trading are different economic instruments, the Gillard government did not see itself in breach of any promise.

While the political debate focused on the semantics of the announcement, the widely-held public opinion was that Gillard's announcement prior to the election meant that there would be no price on carbon *per se*, that is, neither a carbon tax nor an emissions trading scheme. This view was supported by Gillard's proposal in July 2010 to call for a "citizens' assembly" to debate public support for carbon pricing prior to taking any measure, which was ultimately abandoned and created public cynicism about citizen engagement in Australian politics (Boswell et al., 2013). Resource companies and the media accused Gillard of breaking an election promise (Bailey et al., 2012). The 2010 election on August 21 resulted in a hung parliament – Gillard had to form a government with support of the Greens and three independents. On 28 September 2010, Gillard announced that there would be no citizens' assembly, but a "Multi-Party Committee on Climate Change" with the purpose of proposing legislation to be considered by Parliament (Crowley, 2013).

### 2.2. The passage of the clean energy act

On 8 July 2011, Independent member of the Lower House, Wilkie, backed Gillard's proposed Carbon Pricing Mechanism which ensured that Gillard had the numbers to introduce this policy measure.[8] On 10 July 2011, Gillard announced further details regarding the proposed legislation, and eventually introduced a package of 18 bills into parliament on 13 September 2011 that would lead to the implementation of the Carbon Pricing Mechanism.[9] On 12 October 2011, the bills were approved by the Lower House by 74 votes to 72 votes.[10] On 8 November 2011, the bills passed the Senate – with a vote of 36 to 32.[11]

The scheme was meant to operate with a government-determined price of A$23 per ton of carbon dioxide equivalent ($CO_2$-e) for liable entities, rising to A$24.15 per ton from 2013 to 2014, and then be A$25.40 per ton from 2015 to 2016. The pricing mechanism covered approximately 60% of Australia's carbon emissions from electricity generation, stationary energy, landfills, wastewater, industrial processes and fugitive emissions.[12] About 500 companies were liable under the mechanism. The plan was

[3] See also the collection of news by ABC: http://www.abc.net.au/news/2014-07-10/carbon-tax-timeline/5569118

[4] MacKinlay (1997) and Corrado (2011) provide detailed reviews on how the event study method has been applied in finance, economics, and accounting. See also Godfrey (2017), Cahill et al. (2017) and Zheng (2018).

[5] For a more detailed review on these studies, we refer readers to Hjort, I., 2016. Potential climate risks in financial markets: A literature overview. University of Oslo.

[6] https://www.legislation.gov.au/Details/C2011A00131

[7] http://www.abc.net.au/news/2011-02-24/gillard-unveils-carbon-price-details/1955968

[8] http://www.smh.com.au/environment/climate-change/independent-wilkie-backs-gillards-carbon-tax-laws-20110708-1h68i.html

[9] http://www.theaustralian.com.au/national-affairs/prime-minister-julia-gillard-has-introduced-carbon-tax-bills-into-parliament/news-story/6eeb51ce7e8abe48e786143fde2e36bd

[10] http://www.abc.net.au/news/2011-10-12/accusations-fly-as-carbon-bills-pass/3551822

[11] http://www.smh.com.au/business/carbon-tax-gets-green-light-in-senate-20111108-1n4rp.html

[12] http://www.cleanenergyregulator.gov.au/Infohub/CPM/About-the-mechanism

**Table 1**
Timeline and overview of key events.

| Date | Event |
|---|---|
| 24 February 2011 | Former Australian Prime Minister Julia Gillard first announced plans to introduce legislation (The Clean Energy Act) to establish a Carbon Pricing Mechanism (dubbed "carbon tax") from 1 July 2012 onwards |
| 12 October 2011 | A legislative package of measures including the Clean Energy Bill 2011 (the 'Main Bill') and related bills were approved by the Lower House by 74 votes to 72 votes. |
| 8 November 2011 | The bills passed the Senate – with a vote of 36 to 32. |
| 7 September, 2013 | The Coalition wins the federal election. The new Prime Minster Tony Abbott announces legislation to abolish the carbon tax would be before Parliament within 100 days of his victory. |
| 13 November 2013 | Abbott introduces legislation to "axe the carbon tax" into Federal Parliament |
| 17 July 2014 | Abolition of the Carbon Pricing Mechanism |

to roll over the Carbon Pricing Mechanism into an Emissions Trading Scheme in 2015 which did not occur as the legislation was repealed in 2014.

### 2.3. The repeal of the carbon tax

On 14 July 2013, after returning to the prime ministership in June, Kevin Rudd changed the Government's stance on carbon emissions, announcing it would "terminate" the carbon tax and move to an emissions trading scheme (ETS) in 2014 – a year earlier than planned. On 7 September, 2013, the Coalition won the federal election and Tony Abbott (as new Prime Minster of Australia) announced legislation to abolish the carbon tax would be before Parliament within 100 days of his victory. On 13 November 2013, Abbott introduced legislation to "axe the carbon tax" into Federal Parliament, leading to the abolishment of the Carbon Pricing Mechanism on 17 July 2014. As a result, there is now no carbon tax in Australia after the repeal by the Abbot government.

## 3. Methodology

Assuming at time $t$, the price of a stock is $S_t$. We adopt the framework of Hietala et al. (2003), Bhagat et al. (2005), Barraclough et al. (2013) and Borochin and Golec (2016) and write the stock price $S_t$ as the weighted average of expected future stock values in two states[13]:

$$S_t = pS^S{}_{t+k} + (1-p)S^F{}_{t+k} \tag{1}$$

where $S_{t+k}{}^S$ if the future price of the stock if the bill is passed (success) at $t+k$, $S_{t+k}{}^F$ is the future price of the stock if the bill is not passed (fail) at $t+k$, and $p$ is the probability that the bill will be passed at $t$.

Since the carbon tax announcement was a surprise, the news effect of the Gillard announcement can then be expressed as $S_{t+k}{}^F - S_{t-1}$, and the value effect is $S_{t+k}{}^S - S_{t+k}{}^F$.

To isolate the news effect and the value effect, we need to estimate $S_{t+k}{}^S$, $S_{t+k}{}^F$ and $p$. It is infeasible to identify three variables based on only one equation. The estimation, however, becomes identifiable in cases the firm has listed options. Similar to Eq. (1), the value of a single call option written on the stock can be written as:

$$C_t(S_t;X) = p\widehat{C}_t(S^S_{t+k}, \sigma^S_{t+k}; X) + (1-p)\widehat{C}_t(S^F_{t+k}, \sigma^F_{t+k}; X) \tag{2}$$

where $C_t(S_t;X)$ is the price of call option at $t$ with strike price, $X$. $\widehat{C}_t(S^S_{t+k}, \sigma^S_{t+k}; X)$ and $\widehat{C}_t(S^F_{t+k}, \sigma^F_{t+k}; X)$ are the theoretical values of the call option conditional on the future stock price and the future volatility if the bill is successfully passed or fails at $t+k$, respectively.[14]

Using Eq. (1), together with four or more tradable call options in Eq. (2), we are able to estimate five unknown parameters $S_{t+k}{}^S$, $S_{t+k}{}^F$, $p$, $\sigma_{t+k}{}^S$, and $\sigma_{t+k}{}^F$ in a system of equations. Barraclough et al. (2013) and Borochin (2014) show that the parameters can be effectively identified even if they are jointly distributed. With the estimates of these parameters, we can identify the news effect and value effect of the announcement, and assess to what extent the market believes the bill is going to be passed. In Appendix 2, we provide the R code used for solving the systematic equations.

Following Barraclough et al. (2013) and Borochin and Golec (2016), we use call options with exercise prices that are at the money (ATM). Specifically, as in Kelly et al. (2016), we define ATM options as options whose deltas satisfy $0.4 < \Delta < 0.5$.[15] Due to nonlinearity of the options pricing model, we rely on options to bring additional information to the systems of equations. To ensure

[13] As in Barraclough et al. (2013) and Borochin and Golec (2016) we ignore discounting issues given $k$ is relatively short.

[14] Put options are not used as: 1) interdependence between call price and put price through put-call parity; 2) put options are less traded; 3) put options are relatively hard to be priced accurately with the binominal tree method in Cox et al. (1979) or the Black-Sholes model since pricing put options requires short selling stocks, which costs more and maybe even infeasible.

[15] Delta has long been used a measure of moneyness as it reflects the information of time to maturity, implied volatility, and risk-free rat, all of which affect the probability that an option would expire in the money (ITM) with a given strike price (Kelly et al. 2016).

**Table 2**
Firm list.

| Name | Code | Industry | Market value (million dollar) | Affected |
|---|---|---|---|---|
| AGL ENERGY | A:AGLX | Multiutilities | 6690.050 | 1 |
| ALUMINA | A:AWCX | Aluminum | 5783.26 | 1 |
| AMCOR | A:AMCX | Containers & Package | 8615.39 | 0 |
| AMP | A:AMPX | Life Insurance | 11,456.5 | 0 |
| ARRIUM | A:ARIX | Iron & Steel | 3750.57 | 1 |
| AUS.AND NZ.BANKING GP. | A:ANZX | Banks | 62,514.09 | 0 |
| BHP BILLITON | A:BHPX | General Mining | 154,346.1 | 1 |
| BRAMBLES | A:BXBX | Containers & Package | 10,154.71 | 0 |
| COCA-COLA AMATIL | A:CCLX | Soft Drinks | 9064.48 | 0 |
| COMMONWEALTH BK.OF AUS. | A:CBAX | Banks | 81,675.19 | 0 |
| CSL | A:CSLX | Pharmaceuticals | 19,521.71 | 0 |
| FORTESCUE METALS GP. | A:FMGX | Iron & Steel | 20,108.09 | 1 |
| HARVEY NORMAN HOLDINGS | A:HVNX | Broadline Retailers | 3208.19 | 0 |
| INCITEC PIVOT | A:IPLX | Specialty Chemicals | 7133.84 | 1 |
| CIMIC GROUP | A:CIMX | Heavy Construction | 9354.45 | 1 |
| LENDLEASE GROUP | A:LLCX | Real Estate Services | 5078.71 | 0 |
| MACQUARIE GROUP | A:MQGX | Investment Services | 13,112.29 | 0 |
| NATIONAL AUS.BANK | A:NABX | Banks | 55,974.99 | 0 |
| NEWCREST MINING | A:NCMX | Gold Mining | 29,925.91 | 1 |
| OIL SEARCH | A:OSHX | Exploration & Prod. | 9124.57 | 1 |
| ORICA | A:ORIX | Specialty Chemicals | 9342.11 | 1 |
| ORIGIN ENERGY (EX BORAL) | A:ORGX | Multiutilities | 14,078.92 | 1 |
| QBE INSURANCE GROUP | A:QBEX | Reinsurance | 19,194.56 | 0 |
| RIO TINTO | A:RIOX | General Mining | 36,712.66 | 1 |
| SANTOS | A:STOX | Exploration & Prod. | 12,423 | 1 |
| TELSTRA | A:TLSX | Fixed Line Telecom. | 34,467.31 | 0 |
| TOLL HOLDINGS | A:TOLX | Transport Services | 4239.46 | 0 |
| WESFARMERS | A:WESX | Home Improvement Ret. | 32,769.09 | 0 |
| WESTFIELD GROUP | A:WDCX | Retail REITs | 22,120.11 | 0 |
| WESTPAC BANKING | A:WBCX | Banks | 70,643.75 | 0 |
| WOODSIDE PETROLEUM | A:WPLX | Exploration & Prod. | 32,785.35 | 1 |
| WORLEYPARSONS | A:WORX | Oil & Gas Equipment | 6858.38 | 1 |
| WOOLWORTHS | A:WOWX | Food Retail,Wholesale | 32,141.55 | 0 |

This table presents the information of the 33 firms included in the sample. Market value measures the total value of shares outstanding in millions as of 24 February 2011. Affected is a dummy variable that equals to 1 if the firm is in a carbon-intensive industry and 0 otherwise.

liquidity, we also require options to have positive open interest and trading volume. Since all the individual stock options are American style, they are priced using the binominal tree method of Cox et al. (1979).

## 4. Data sources and sample attributes

Our sample includes all Australian listed firms with traded options around the Carbon tax announcement date (24 February 2011). We exclude firms that were close to delisting. After this data filtering procedure, we are left with 33 firms. The firm list and their characteristics are presented in Table 2. Our sample covers near equally for carbon-intensive (15 firms) and less intensive industries (18 firms). There is no need for firms to have survived for the entire period for our methodology as our estimates are made ex-ante at the time of the announcement. However, for the robustness intervening event method (Bhagat et al., 2005; see later sections), there is a requirement of survivorship as the estimation is made ex-post comparing the intervening event to the announcement event. Stock data are obtained from Datastream. The relevant fields are closing price, return, cash dividends, ex-dividend date, trading volume, and shares outstanding. Stock option data are also drawn from Datastream. The file includes daily closing option price, trading volume, delta, open interest, exercise price, and maturity. The market value of the sample firms ranges from A$3.21 billion dollars (HVN) to A$154.35 billion dollars (BHP), indicating that we have covered both small and big firms in the Australian stock market. Comparing the market values of the two groups, the average market value of “affected firms” is A$23.89 billion dollars, while the “unaffected firms” has a larger average market value at A$27.55 billion dollars.

The valuation of options and the computation of implied volatilities require a proxy for the risk free rate of interest. Following Frijns et al. (2010), we use the Australia bank bill rate. 30-day, 90-day, and 180-day nominal rates are downloaded from Datastream and converted into continuous rates. The interest rate for a particular maturity $t$ is computed by linearly interpolating between the two continuous rates whose maturities straddle $t$. We proxy for expected dividends by using the actual dividend paid over the option's life, adjusted for stock dividends paid during the option's life.[16]

[16] There are no share splits for all the stocks in our sample period. Henceforth, there is no adjustment for share splits needed.

**Table 3**
Summary of market activity of call options during the Gillard announcement.

| | Pre-announcement day | Announcement day | | After-announcement day | |
|---|---|---|---|---|---|
| Trading volume | Mean | Mean | %Change | Mean | %Change |
| Whole sample | 56.91*** | 96.65*** | 69.8%** | 71.40*** | −26.1% |
| | (4.207) | (6.543) | (2.242) | (3.106) | (−1.043) |
| Affected firms | 46.88** | 99.76*** | 112.8%*** | 42.79*** | −57.1%** |
| | (2.167) | (3.848) | (2.770) | (3.469) | (−1.970) |
| Non-affected firms | 65.34*** | 95.65*** | 46.4% | 94.01** | −1.70% |
| | (3.870) | (5.941) | (1.336) | (2.255) | (−0.009) |

This table reports the trading volume of the options around the carbon tax announcement date (24 February 2011). The pre-announcement day is one day before the announcement. The announcement day is the day of the carbon tax announcement. The after-announcement day is one day after the announcement. T-statistics are reported in the parentheses. ** and *** denote the significance at 5% and 1% respectively.

## 5. Results

### 5.1. Option market activity around the carbon tax announcement

We summarize the market activity of call options written on the 33 stocks during the Gillard carbon tax announcement period. As in Barraclough et al. (2013), we focus on trading volume. We first sum across all call option series for each stock on the pre-announcement day (23 February 2011), announcement day (24 February 2011), and post-announcement day (25 February 2011). We then average across all firms. Compared to the pre-announcement day, the average trading volume for the whole sample increased by about 70% (see Table 3), and decreased by about 26% one day later. Moreover, carbon-intensive firms experienced a significant increase in trading volume of more than 112% from the pre-announcement day to the announcement, while the other group increased by 46%. Taken together these results provide compelling evidence that option market contains valuable information towards the carbon tax announcement.[17] This further validates our method.

### 5.2. Estimation results

After selecting the sample firms, we now turn to estimating the model on the Gillard carbon tax announcement day (24 February 2011). The model is defined by the stock and option pricing Eqs. (1) and (2) on the announcement day of our sample of mergers. The key parameters are the probability of success, $p$, stock price if successful, $S_{t+k}{}^{S}$, the stock price if unsuccessful. With reliable estimates of these parameters, we can identify the sources of the announcement effect. We estimate the model for each of the 33 firms. For comparison, we also calculate the raw return and abnormal return for the announcement day. As in Barraclough et al. (2013), we calculate the abnormal return as the difference between raw return and market return (using ASX 200 index return as the proxy).

We present the full estimation results for our 33 sample firms in Appendix 1. Panel A of Table 4 summarizes the estimation results for the whole sample analysis. On average, we can find that the raw return and abnormal return for 33 firms are −0.68% and −0.53% on average, which are both significant at 1%, indicating that carbon tax announcement has a destructive effect on firm value. However, the drawback of the simple return analysis lies on the fact it cannot distinguish the sources of the announcement effect. Instead, our method addresses this issue. The average expected probability that the act would be passed (success) is 42.4%, which is significant at 1% with a standard error of 14.7%. Since the Labor party was not the majority in the Parliament, Gillard needed the support from the Greens and three independents to get the bill passed (especially in the Lower House). Our probability estimate at 42.4% is consistent with this political uncertainty.

Our findings distinguish between the two sources of the announcement effect. The average news effect is positively significant at 1.11%, while the average value effect is negatively significant at −4.46%. In terms of dollar value, the news effect is 254.46 million dollars per firm on average, and the value effect is −1123.45 million dollars per firm on average. The positive news effect suggests that the market viewed positively the news that government was planning on acting decisively on climate change. This finding is also consistent with survey evidence that most Australian people find a carbon tax acceptable (Dreyer and Walker, 2013). The negative value effect, however, suggests that the carbon tax was value-destructive for existing firms. It is consistent with the findings that a carbon tax will significantly increase production costs and cause economic contraction (Meng et al., 2013). When analysing the announcement effects of green policies in the Australian market, both Ramiah et al. (2013) and Chapple et al. (2013) find a negative effect using the standard event study method. Our results show that the primary driver of the negative announcement effect is the value effect.

Since different sectors may have distinctive exposures to carbon risk (Ramiah et al., 2013, 2015), we further conduct a sub-sample analysis. Specifically, we divide 33 firms into two groups. One group contains the carbon-intensive firms that are expected to pay carbon tax, and the other group contains the firms that (ex-ante) are unlikely to be subject to the carbon tax. The results are presented

[17] Kelly et al. (2016) provide strong evidence that investors take positions in the option market to hedge the policy risk, e.g., US presidential election.

**Table 4**
News and value effects estimation results.

| No. | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw return |
|---|---|---|---|---|---|---|---|
| | Panel A: Whole sample | | | | | | |
| 33 | 42.4%*** | −4.64%*** | −1123.45*** | 1.11%*** | 254.46** | −0.53%*** | −0.68%*** |
| | (16.284) | (−7.561) | (−3.620) | (3.580) | (2.349) | (−2.779) | (−3.577) |
| | Panel B: Affected firms | | | | | | |
| No. | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw Return |
| 15 | 39.5%*** | −6.41%*** | −1359.63** | 0.99%** | 329.16 | −1.04%*** | −1.19%*** |
| | (10.043) | (−6.170) | (−2.303) | (2.351) | (1.545) | (−3.600) | (−4.123) |
| | Panel C: Non-affected firms | | | | | | |
| No. | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw Return |
| 18 | 45.2%*** | −3.17%*** | −926.65*** | 1.20%*** | 192.22** | −0.09% | −0.25% |
| | (13.189) | (−5.975) | (−3.121) | (2.647) | (2.043) | (−0.480) | (−1.208) |
| | Panel D: Difference between two groups | | | | | | |
| | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw Return |
| | −5.65% | −3.23%*** | −432.98 | −0.21% | 136.94 | −0.94%** | −0.94%** |
| | (−1.0836) | (−2.772) | (−0.655) | (−0.351) | (0.588) | (−2.640) | (−2.640) |

This table reports the news and value effects of the carbon tax announcement on 24 February 2011. Probability is the estimated probability that the carbon tax bill would be passed in the Parliament. Value effect is the percentage difference between the theoretical price in the state of bill passage and the theoretical price in the state of bill failure. News effect is the percentage difference between the theoretical price in the state of bill failure and the price one day before the announcement (24 February 2011). CAR is the announcement day return subtracted by market return. Raw return is the announcement day return. We also report the value of the effects (in million dollars) by multiplying the percentage-based news and values effects with the market value of the stock. Panel A reports the results for the whole sample. Panel B reports the results for affected firms. Panel C reports the results for non-affected firms. Panel D reports the difference between affected firms and non-affected firms. t-statistics are reported in the parentheses. *,** and *** denote the significance at 10%, 5% and 1% respectively.

in Panel B and Panel C respectively. The results show that these two groups have insignificantly different success probability and news effect. Since these two parameters by theory should only reflect market investors' perceptions towards the climate policy, the documented insignificant difference further validates our method. Consistent with our expectation, there is a sharp difference for the value effect but not the news effect between the two groups. The average value effect for the group with "affected firms" is −6.41%, while it is only −3.17% for the "unaffected firms". The difference is significant at the 1% level. In terms of dollar values, the "affected firms" would lose A$1.36 billion dollars on average, and the "unaffected firms" would lose A$926.65 million dollars on average.[18] Although the magnitude of the value effect is smaller for "unaffected firms", it is still significant, indicating that the carbon tax has an overall negative effect on the market. This is in line with the existing studies which find that a carbon tax has an adverse effect on the industries that are not tax payers (Dwyer et al., 2013; Meng, 2015).

### 5.3. Robustness check: excluding confounding events

One critical factor to implement this method is to exclude confounding events (Borochin and Golec, 2016) as otherwise it is unclear to identify the source of price changes. With this in mind, we conduct a robustness check by excluding significant firm events close to the Gillard carbon tax announcement date. We search for all the relevant firm events in the [−1, +1] window (23, 24, and 25 February) from Bloomberg. We find 12 firms have earnings announcements in this period. To ensure our results are not driven by investors' reactions to earnings news, we summarize the estimation results in Table 5 without including these 12 firms. We find close estimates for all the variables of interest. The probability of successful passage is at 43.9%, the value effect is on average −4.93% for all the firms, −6.97% for "affected firms", and −3.67% for "unaffected firms". Overall, our findings are robust.

### 5.4. Comparison with alternative approaches

We also compare our approach with the intervening event method of Bhagat et al. (2005). The difficulty with this intervening method however is that it is specific to the particular source of uncertainty, for example takeover, class action suit, divestment or legislation announcement. Bhagat et al. (2005) use past takeover events to estimate a prior takeover probability and then use competing bids as intervening events. In our legislative situation, since we have a hung parliament we can estimate the probability of major legislation using past events. Given the success rate of double dissolutions in a hung parliament,[19] a probability of 50% seems

[18] The dollar value difference is not statistically significant. This is because "unaffected firms" have a larger market value on average than the "affected firms" as shown in Section 4. The total dollar value effect for the 15 affected firms is A$1.36 billion dollars *15 = A$20.4 billion dollars while it is A$$926.65 million dollars *18 = A$16.67 billion dollars for the 18 unaffected firms.

[19] See http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp1415/FedElect

**Table 5**
News and value effects estimation results (excluding confounding events).

| No. | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw return |
|---|---|---|---|---|---|---|---|
| | Panel A: Whole sample | | | | | | |
| 21 | 43.9%*** | −4.93%*** | −1010.76*** | 1.51%*** | 234.92*** | −0.40%** | −0.56%* |
| | (12.484) | (−6.717) | (−3.857) | (3.620) | (2.578) | (−2.049) | (−1.651) |
| | Panel B: Affected firms | | | | | | |
| | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw Return |
| 8 | 41.9%*** | −6.97%*** | −875.3** | 1.78%*** | 297.78** | −0.77%*** | −0.92%*** |
| | (6.888) | (−5.159) | (−3.491) | (3.857) | (2.239) | (−3.437) | (−4.113) |
| | Panel C: Non-affected firms | | | | | | |
| | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw Return |
| 13 | 45.2%*** | −3.67%*** | −1094.1*** | 1.34%** | 196.24 | −0.18% | −0.33% |
| | (10.173) | (−5.488) | (−2.728) | (2.164) | (1.567) | (−0.657) | (−1.204) |
| | Panel D: Difference between two groups | | | | | | |
| | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw Return |
| | −3.3% | −3.3%** | 218.8 | 0.44% | 101.54 | −0.59% | −0.59% |
| | (−0.425) | (−2.200) | (0.463) | (0.561) | (0.555) | (−1.651) | (−1.651) |

This table summarizes the news and value effects of the carbon tax announcement on 24 February 242,011 by excluding firms with confounding events. Probability is the estimated probability that the carbon tax bill would be passed in the Parliament. Value effect is the percentage difference between the theoretical price in the state of bill passage and the theoretical price in the state of bill failure. News effect is the percentage difference between the theoretical price in the state of bill failure and the price one day before the announcement (24 February 2011). CAR is the announcement day return subtracted by market return. Raw Return is the announcement day return. We also report the value of the effects (in million dollars) by multiplying the percentage based news and values effects with the market value of the stock. Panel A reports the results for the whole sample. Panel B reports the results for affected firms. Panel C reports the results for non-affected firms. Panel D reports the difference between affected firms and non-affected firms. t-statistics are reported in the parentheses. *,** and *** denote the significance at 10%, 5% and 1% respectively.

**Table 6**
News and value effects estimation results (intervening event method).

| No. | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw return |
|---|---|---|---|---|---|---|---|
| | Panel A: Whole sample | | | | | | |
| 33 | 50% | −17.10%*** | −3736.30*** | 7.86%*** | 1674*** | −0.53%*** | −0.68%*** |
| | | (−5.074) | (−3.732) | (4.762) | (3.680) | (−2.779) | (−3.577) |
| | Panel B: Affected firms | | | | | | |
| No. | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw Return |
| 15 | 50% | −16.44%** | −2658.4* | 7.10%** | 1103.13* | −1.04%*** | −1.19%*** |
| | | (−2.892) | (−2.051) | (2.609) | (2.057) | (−3.600) | (−4.123) |
| | Panel C: Non-affected firms | | | | | | |
| No. | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw Return |
| 18 | 50% | −17.72%*** | −4750*** | 8.57%*** | 2213*** | −0.09% | −0.25% |
| | | (−4.496) | (−3.150) | (4.301) | (3.088) | (−0.480) | (−1.208) |
| | Panel D: Difference between two groups | | | | | | |
| | Probability | Value effect | Value effect (dollar, million) | News effect | News effect (dollar, million) | CAR | Raw Return |
| | 0% | 1.28% | 2091.60 | −1.47% | −1110 | −0.94%** | −0.94%** |
| | | (0.185) | (1.052) | (−0.437) | (−1.240) | (−2.640) | (−2.640) |

This table summarizes the estimated news and value effects of the carbon tax announcement using the intervening event method. Probability is the probability that the carbon tax bill would be passed in the Parliament, and is set to be 50%. Value effect is the percentage difference between the theoretical price in the state of bill passage and the theoretical price in the state of bill failure. News effect is the percentage difference between the theoretical price in the state of bill failure and the price one day before the announcement (24 February 2011). CAR is the announcement day return subtracted by market return. Raw return is the announcement day return. We also report the value of the effects (in million dollars) by multiplying the percentage based news and values effects with the market value of the stock. Panel A reports the results for the whole sample. Panel B reports the results for affected firms. Panel C reports the results for non-affected firms. Panel D reports the difference between affected firms and non-affected firms. t-statistics are reported in the parentheses. *,** and *** denote the significance at 10%, 5% and 1% respectively.

reasonable. The intervening event we use is the announcement by the independents that they would support the carbon tax legislation on 8 July 2011. At this stage the probability of passage of the legislation goes to 100%. If we assume that the $S_{t+k}{}^{S}$(the theoretical price given the bill is passed) has not changed since the original announcement the traded price at the time of the intervening event is then equal to $S_{t+k}{}^{S}$.

We can now go back to Eq. (1) at the time of the announcement. Since we assume $p$ is 50% at the time of the announcement and we know $S_{t+k}{}^{S}$ equals the traded price at the intervening event, the only unknown variable is $S_{t+k}{}^{F}$, which can be easily estimated.

Table 6 gives the news effect and the valuation effect under the intervening event scenario. We find that consistent with the estimation results in Table 3, there is a negative value effect but a positive news effect associated with the carbon tax announcement. However, the magnitudes are much larger compared to our main results. For the whole sample, on average, the news effect is significant at 7.86%, and the value effect is significant at −17.10%, which are unreasonably high in magnitudes compared to both our method and other studies on green policies (e.g., Chapple et al., 2013; Ramiah et al., 2013). Moreover, when comparing the value effects within two groups, the average value effect for "affected" firms is −16.44% while it is −17.72% for "unaffected firms". The difference is not statistically significant and is in sharp contrast with our previous findings in Table 3 that "affected" firms react more negatively.

This comparison provides confirming evidence that the method we adopt can measure the value and wealth effect of announcements more accurately. In practice, our method can be applied to estimate the *ex-ante* wealth and news effects for any announcement or event with unresolved uncertainty as long as there are traded options on the targets of interest. In contrast, the intervening event method of Bhagat et al. (2005) can only estimate the wealth effect *ex-post.* The method also depends heavily on the existence of intervening events and a reliable prior probability estimator, and has to be tailored to each type of announcement. In contrast, our method can be applied in the same way to every type of announcement with unresolved uncertainty.

## 6. Conclusion

In this study, we study the wealth effects associated with the 2011 carbon tax announcement in Australia. Since it was uncertain whether the proposed carbon tax bill would eventually pass Parliament or not, the traditional event study method of Fama et al. (1969) and Ball and Brown (1968) cannot be applied – the price on announcement contains an outcome probability parameter as well as outcome price parameters. To solve this issue, we adopt the most recent event study approach developed by Barraclough et al. (2013) and Borochin and Golec (2016) to isolate the news and value effects from price changes. We find that the news effect is 1.11% (254.46 million dollars) and value effect is −4.46% (−A$1.12 billion dollars) for an average Australian firm. We also show that the announcement of the Australian Carbon Pricing Scheme had a more negative value effect for carbon-intensive firms (−6.97%, or −A$13.59 billion dollars) than for the other firms (−3.67%, or −A$926.65 million dollars). This percentage difference is significant at 1%. Our results indicate that the market viewed positively the news that the government was taking decisive action on climate change; however, the carbon tax was value destroying for existing firms. Our findings are robust to excluding confounding events and comparison with alternative methods such as the intervening event method of Bhagat et al. (2005). While we focus only on the Australian Carbon Pricing Scheme in this study, our method can be applied to any policy announcements with unresolved uncertainty and is particularly useful for research in the emerging environmental finance area, where quantifying the wealth effects and investment implications of green policies is of primary importance (Linnenluecke et al., 2016, 2017).

## Appendix 1: full estimation results

| Code | PS/P | Pf/P | P | P{−1} | Prob (S) | Rm | P/P{−1}-1 | CAR | Pf/P{−1}-1 (news) | Ps/pf −1 (net value) | Ps/P{−1}-1 | Market value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A:AGLX | 0.972 | 1.012 | 14.600 | 14.460 | 0.304 | −0.002 | 0.010 | 0.011 | 0.022 | −0.040 | −0.019 | 6690.050 |
| A:AMCX | 0.979 | 1.027 | 7.030 | 7.110 | 0.557 | −0.002 | −0.011 | −0.010 | 0.015 | −0.048 | −0.032 | 8615.390 |
| A:AMPX | 0.987 | 1.045 | 5.470 | 5.460 | 0.773 | −0.002 | 0.002 | 0.003 | 0.047 | −0.059 | −0.011 | 11,456.500 |
| A:ANZX | 0.965 | 1.018 | 24.080 | 24.210 | 0.334 | −0.002 | −0.005 | −0.004 | 0.012 | −0.052 | −0.040 | 62,514.090 |
| A:AWCX | 1.000 | 1.000 | 2.370 | 2.390 | 0.508 | −0.002 | −0.008 | −0.007 | −0.008 | −0.001 | −0.009 | 5783.260 |
| A:BHPX | 0.973 | 1.032 | 45.990 | 46.570 | 0.538 | −0.002 | −0.012 | −0.011 | 0.020 | −0.060 | −0.040 | 154,346.100 |
| A:BXBX | 0.973 | 1.028 | 7.000 | 7.080 | 0.516 | −0.002 | −0.011 | −0.010 | 0.016 | −0.055 | −0.038 | 10,154.710 |
| A:CBAX | 0.999 | 1.001 | 52.730 | 53.190 | 0.442 | −0.002 | −0.009 | −0.007 | −0.008 | −0.001 | −0.009 | 81,675.190 |
| A:CCLX | 0.986 | 1.038 | 11.990 | 11.680 | 0.713 | −0.002 | 0.027 | 0.028 | 0.065 | −0.052 | 0.012 | 9064.480 |
| A:CSLX | 0.967 | 1.013 | 35.840 | 36.000 | 0.288 | −0.002 | −0.004 | −0.003 | 0.009 | −0.046 | −0.037 | 19,521.710 |
| A:FMGX | 0.931 | 1.018 | 6.460 | 6.540 | 0.204 | −0.002 | −0.012 | −0.011 | 0.005 | −0.087 | −0.081 | 20,108.090 |
| A:HVNX | 0.996 | 1.003 | 3.020 | 3.000 | 0.422 | −0.002 | 0.007 | 0.008 | 0.010 | −0.008 | 0.002 | 3208.190 |
| A:IPLX | 0.956 | 1.010 | 4.380 | 4.430 | 0.177 | −0.002 | −0.011 | −0.010 | −0.002 | −0.054 | −0.055 | 7133.840 |
| A:CIMX | 0.879 | 1.029 | 30.260 | 30.460 | 0.193 | −0.002 | −0.007 | −0.005 | 0.022 | −0.150 | −0.127 | 9354.450 |
| A:LLCX | 0.973 | 1.023 | 8.980 | 9.050 | 0.465 | −0.002 | −0.008 | −0.006 | 0.015 | −0.050 | −0.035 | 5078.710 |
| A:MQGX | 0.977 | 1.026 | 37.810 | 38.080 | 0.528 | −0.002 | −0.007 | −0.006 | 0.018 | −0.048 | −0.030 | 13,112.290 |
| A:NABX | 0.967 | 1.018 | 25.800 | 25.820 | 0.352 | −0.002 | −0.001 | 0.001 | 0.017 | −0.051 | −0.034 | 55,974.990 |
| A:NCMX | 0.983 | 1.018 | 39.110 | 38.940 | 0.512 | −0.002 | 0.004 | 0.006 | 0.022 | −0.034 | −0.013 | 29,925.910 |
| A:ORGX | 0.908 | 1.017 | 15.460 | 16.010 | 0.157 | −0.002 | −0.034 | −0.033 | −0.018 | −0.109 | −0.123 | 14,078.920 |
| A:ORIX | 0.965 | 1.014 | 25.720 | 26.020 | 0.280 | −0.002 | −0.012 | −0.010 | 0.002 | −0.049 | −0.046 | 9342.110 |
| A:OSHX | 0.975 | 1.020 | 6.950 | 6.940 | 0.443 | −0.002 | 0.001 | 0.003 | 0.021 | −0.045 | −0.024 | 9124.570 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A:ARIX | 0.952 | 1.056 | 2.810 | 2.860 | 0.535 | −0.002 | −0.017 | −0.016 | 0.037 | −0.104 | −0.065 | 3750.570 |
| A:QBEX | 0.985 | 1.014 | 18.250 | 18.290 | 0.501 | −0.002 | −0.002 | −0.001 | 0.012 | −0.029 | −0.017 | 19,194.560 |
| A:RIOX | 0.973 | 1.038 | 84.250 | 84.960 | 0.587 | −0.002 | −0.008 | −0.007 | 0.029 | −0.065 | −0.035 | 36,712.660 |
| A:TOLX | 0.929 | 1.031 | 6.000 | 6.200 | 0.304 | −0.002 | −0.032 | −0.031 | −0.002 | −0.102 | −0.101 | 4239.460 |
| A:WBCX | 0.949 | 1.012 | 23.480 | 23.660 | 0.193 | −0.002 | −0.008 | −0.006 | 0.004 | −0.063 | −0.058 | 70,643.750 |
| A:WDCX | 0.998 | 1.002 | 9.580 | 9.680 | 0.510 | −0.002 | −0.010 | −0.009 | −0.008 | −0.005 | −0.013 | 22,120.110 |
| A:WESX | 0.999 | 1.001 | 32.600 | 32.970 | 0.470 | −0.002 | −0.011 | −0.010 | −0.010 | −0.003 | −0.013 | 32,769.090 |
| A:WORX | 0.967 | 1.035 | 29.730 | 29.190 | 0.510 | −0.002 | 0.018 | 0.020 | 0.054 | −0.068 | −0.015 | 6858.380 |
| A:WOWX | 0.986 | 1.013 | 26.500 | 26.490 | 0.507 | −0.002 | 0.000 | 0.002 | 0.013 | −0.026 | −0.013 | 32,141.550 |
| A:WPLX | 0.997 | 1.002 | 41.850 | 42.480 | 0.438 | −0.002 | −0.015 | −0.013 | −0.013 | −0.005 | −0.017 | 32,785.350 |
| A:STOX | 0.999 | 1.001 | 14.210 | 14.350 | 0.360 | −0.002 | −0.010 | −0.008 | −0.009 | −0.002 | −0.011 | 12,423.000 |
| A:TLSX | 0.997 | 1.002 | 2.770 | 2.790 | 0.379 | −0.002 | −0.007 | −0.006 | −0.005 | −0.005 | −0.010 | 34,467.310 |
| Average | 0.971 | 1.018 | 21.208 | 21.353 | 0.424 | −0.002 | −0.007 | −0.005 | 0.011 | −0.046 | −0.035 | 26,656.137 |

This table reports the full estimation results for all the 33 firms. PS stands for the theoretical price in the state of bill passage, Pf stands for the theoretical price in the state of bill failure, P stands for the daily closing price on 24 February 2011, P{−1} stands for the daily closing price one day prior to the carbon tax announcement (23 February 2011), Rm stands for the market return (using ASX 200 index return as a proxy) on 24 February 2011, CAR is defined as the difference between daily stock return on 24 February 2011 and the market return (Rm), and market value stands for the market value of shares outstanding of each firm on the announcement date.

## Appendix 2: R code

```
###americancalloption
library(AmericanCallOpt);
###equation1: stock price error
eps < - function(params) {
 actual_price - params["prob"] * params["price1"]*actual_price - (1 - params["prob"]) * params["price2"]*actual_price
}
###option price error
epo < - function(params){
 if (dvdate < t){
 option_price-params["prob"]*am_call_bin_propdiv(params["price1"]*actual_price,strike,rf,params["sigma1"],t,-
steps=100,dvdate,y)-(1-params["prob"])*am_call_bin_propdiv(params["price2"]*actual_price,strike,rf,params["sigma2"],t,-
steps=100,dvdate,y)
 }
 else{option_price-params["prob"]*am_call_bin(params["price1"]*actual_price,strike,rf,params["sigma1"],t,steps=100)-(1-params
["prob"])*am_call_bin(params["price2"]*actual_price,strike,rf,params["sigma2"],t,steps=100)
 }
}
###objective function
obj < - function(params){
 if(params["prob"] < =0 | params["prob"] > = 1 |
   params["price1"] < = 0 | params["price2"] < = 0 |
   params["sigma1"] < = 0 | params["sigma2"] < = 0) {
  10^9
 }
 else{
  actual_price < < -opt$OUP[1];
  err=eps(params)^2;
  for (num in 1:nrow(opt)){
   option_price < < -opt$MP[num];
   strike < < -opt$strike[num];
   rf < < -opt$rf[num];
   t < < -opt$T[num];
   dvdate < < -opt$dvdate[num];
   y < < -opt$y[num];
   err=err+epo(params)^2;
  }
  return(err);
 }
}
theday=read_csv("theday.csv") ### input data
result=matrix(0,2*length(firmi),8);
for (i in 1:length(firmi)){
```

```
 opt = subset(theday,name = = firmi[i]);
 iniparams = c(prob = 0.5,price1 = 0.9,price2 = 1.1,sigma1 = mean(opt$VL),sigma2 = mean(opt$VL));
 optresult = optimx(iniparams,obj,lower = c(0.01, 0.01, 0.01, 0.001, 0.001), upper = c(0.99, 2, 2, 2, 2),method = c("L-BFGS-B",
"nlminb"), itnmax = NULL);
 resultopt = subset(optresult,value = = min(optresult$value))
 if (resultopt$value < 1000){
  iniparams = c(prob = resultopt$prob,price1 = resultopt$price1,price2 = resultopt$price2,sigma1 = resultopt$sigma1,sigma2 = r-
esultopt$sigma2);
  optresult2 = optimx(iniparams,obj,lower = c(0.01, 0.01, 0.01, 0.001, 0.001), upper = c(0.99, 2, 2, 2, 2),method = c("L-BFGS-B",
"nlminb"), itnmax = NULL);
  result[((i-1)*2 + 1):(i*2),1:6] = as.matrix(optresult2[1:6]);
  result[((i-1)*2 + 1):(i*2),7] = matrix(firmi[i],2,1);
  result[((i-1)*2 + 1):(i*2),8] = rownames(optresult2)
 }
}
result = data.frame(result);
names(result) = c("prob","price1","price2","sigma1","sigma2","error","name","optimmethod")
```

## References


Bailey, I., MacGill, I., Passey, R., Compston, H., 2012. The fall (and rise) of carbon pricing in Australia: a political strategy analysis of the carbon pollution reduction scheme. Environ Politics 21, 691–711.

Ball, R., Brown, P., 1968. An empirical evaluation of accounting income numbers. J. Account. Res. 6, 159–178.

Barraclough, K., Robinson, D.T., Smith, T., Whaley, R.E., 2013. Using option prices to infer overpayments and synergies in M&A transactions. Rev. Financ. Stud. 26, 695–722.

Bhagat, S., Dong, M., Hirshleifer, D., Noah, R., 2005. Do tender offers create value? New methods and evidence. J. Financ. Econ. 76, 3–60.

Borochin, P.A., 2014. When does a merger create value? Using option prices to elicit market beliefs. Financ. Manag. 43, 445–466.

Borochin, P., Golec, J., 2016. Using options to measure the full value-effect of an event: application to Obamacare. J. Financ. Econ. 120, 169–193.

Boswell, J., Niemeyer, S., Hendriks, C.M., 2013. Julia Gillard's citizens' assembly proposal for Australia: a deliberative democratic analysis. Aust. J. Polit. Sci. 48, 164–178.

Cahill, D., Wee, M., Yang, J.W., 2017. Media sentiment and trading strategies of different types of traders. Pac. Basin Financ. J. 44, 160–172.

Chapple, L., Clarkson, P.M., Gold, D.L., 2013. The cost of carbon: capital market effects of the proposed emission trading scheme (ETS). Abacus 49, 1–33.

Corrado, C.J., 2011. Event studies: a methodology review. Account Fin 51, 207–234.

Cox, J.C., Ross, S.A., Rubinstein, M., 1979. Option pricing: a simplified approach. J. Financ. Econ. 7, 229–263.

Crowley, K., 2013. Pricing carbon: the politics of climate policy in Australia. Wiley Interdiscip. Rev. Clim. Chang. 4 (6), 603–613.

Dreyer, S.J., Walker, I., 2013. Acceptance and support of the Australian carbon policy. Soc. Justice Res 26, 343–362.

Dwyer, L., Forsyth, P., Spurr, R., Hoque, S., 2013. Economic impacts of a carbon tax on the Australian tourism industry. J. Travel Res. 52, 143–155.

Fama, E.F., Fisher, L., Jensen, M.C., Roll, R., 1969. The adjustment of stock prices to new information. Int. Econ. Rev. 10, 1–21.

Frijns, B., Tallau, C., Tourani-Rad, A., 2010. The information content of implied volatility: evidence from Australia. J. Futur. Mark. 30, 134–155.

Godfrey, K.R., 2017. Toward a model-free measure of market efficiency. Pac. Basin Financ. J. 44, 97–112.

Griffin, P.A., Lont, D.H., Sun, E.Y., 2017. The relevance to investors of greenhouse gas emission disclosures. Contemp. Account. Res. 34, 1265–1297.

Hietala, P., Kaplan, S.N., Robinson, D.T., 2003. What is the price of hubris? Using takeover battles to infer overpayments and synergies. Financ. Manag. 32, 5–31.

Hjort, I., 2016. Potential Climate Risks in Financial Markets: A Literature Overview. University of Oslo.

IPCC, 2014. Climate Change 2014–Impacts, Adaptation and Vulnerability. Cambridge University Press.

IPCC, 2018. Global warming of 1.5 °C: An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Summary for Policymakers. Available at. http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf.

Kelly, B., Pástor, Ľ., Veronesi, P., 2016. The price of political uncertainty: theory and evidence from the option market. J. Financ. 71, 2417–2480.

Kim, E.-H., Lyon, T., 2011. When does institutional investor activism increase shareholder value? The carbon disclosure project. BE J Econom Anal Policy 11.

Lee, S.Y., Park, Y.S., Klassen, R.D., 2015. Market responses to firms' voluntary climate change information disclosure and carbon communication. Corp. Soc. Responsib. Environ. Manag. 22, 1–12.

Linnenluecke, M.K., Chen, X., Ling, X., Smith, T., Zhu, Y., 2016. Emerging trends in Asia-Pacific finance research: a review of recent influential publications and a research agenda. Pac. Basin Financ. J. 36, 66–76.

Linnenluecke, M.K., Chen, X., Ling, X., Smith, T., Zhu, Y., 2017. Research in finance: a review of influential publications and a research agenda. Pac. Basin Financ. J. 43, 188–199.

Linnenluecke, M.K., Smith, T., McKnight, B., 2016. Environmental finance: a research agenda for interdisciplinary finance research. Econ. Model. 59, 124–130.

MacKinlay, A.C., 1997. Event studies in economics and finance. J. Econ. Lit. 35, 13–39.

Meinshausen, M., Meinshausen, N., Hare, W., Raper, S.C., Frieler, K., Knutti, R., Frame, D.J., Allen, M.R., 2009. Greenhouse-gas emission targets for limiting global warming to 2 C. Nature 458, 1158–1162.

Meng, S., 2015. Is the agricultural industry spared from the influence of the Australian carbon tax? Agric. Econ. 46, 125–137.

Meng, S., Siriwardana, M., McNeill, J., 2013. The environmental and economic impact of the carbon tax in Australia. Environ. Resour. Econ. 54, 1–20.

Pindyck, R.S., 2013. Climate change policy: what do the models tell us? J. Econ. Lit. 51, 860–872.

Ramiah, V., Martin, B., Moosa, I., 2013. How does the stock market react to the announcement of green policies? J. Bank. Financ. 37, 1747–1758.

Ramiah, V., Pham, H.N.A., Wang, I., Dang, V.N.T., Veron, J.F., Duong, H., 2017. The financial consequences of abolishing a carbon trading system. Appl. Econ. Lett. 24, 936–939.

Ramiah, V., Pichelli, J., Moosa, I., 2015. Environmental regulation, the Obama effect and the stock market: some empirical results. Appl. Econ. 47, 725–738.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., 2009. A safe operating space for humanity. Nature 461, 472–475.

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., Sörlin, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 347.

Zheng, L., 2018. The type of corporate announcements and its implication on trading behaviour. Accounting Fin In Press. https://onlinelibrary.wiley.com/doi/abs/10.1111/acfi.12356.